Evaluation of MerCAP™ for Power Plant Mercury Control

Quarterly Technical Progress Report

January 1, 2005 – March 31, 2005

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Cooperative Agreement No: DE-FC26-03NT41993

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ABSTRACT

This document summarizes progress on Cooperative Agreement DE-FC26-03NT41993, "Evaluation of MerCAP™ for Power Plant Mercury Control," during the time-period January 1, 2005 through March 31, 2005. The objective of this project is to demonstrate the performance of MerCAP™, a technology that uses a fixed sorbent downstream of wet and dry scrubbers for removing mercury from coal-combustion flue gas. The project is being funded by the U.S. DOE National Energy Technology Laboratory under this Cooperative Agreement. EPRI, Great River Energy, and Southern Company are project co-funders. URS Group is the prime contractor.

The general concept for MerCAP™ is to place fixed structure sorbents into a flue gas stream to adsorb mercury and then, as the sorbent surfaces become saturated, thermally or chemically regenerate the sorbent and recover the mercury. One example includes parallel gold-coated plates. Mercury forms an amalgam with the gold and is removed from the flue gas flowing past the plates. The captured mercury can be subsequently sequestered using a carbon canister or cryogenic trap during regeneration.

In this project, URS Group and its team are conducting tests at two host power plants to evaluate gold MerCAP™ performance downstream of a spray dryer-baghouse and wet scrubber over an extended period of flue-gas exposure. The spray dryer site, Site 1, is Great River Energy's Stanton Station, which burns a ND lignite coal and a Powder River Basin (PRB) sub-bituminous coal. At this site, an array of gold-coated MerCAP™ plates are incorporated into the outlet plenum of one compartment (6 Megawatt Equivalent (MWe)) of the Unit 10 baghouse. Site 2, the wet scrubber site, is Southern Company Services' Plant Yates Unit 1, which burns an Eastern bituminous coal. An array of gold-coated structures will be configured in a 2800 actual cubic foot per minute (acfm) slipstream (1 MWe) receiving flue gas immediately downstream of a full-scale FGD absorber. MerCAP™ will be evaluated for mercury removal during normal boiler operation for periods of six months at both sites.

MerCAP™ technology has been successfully tested in small-scale units installed at the proposed test sites. Results of this study will verify this performance at a larger scale and over a longer period of gas exposure and will provide data required for assessing the feasibility and costs of a full-scale MerCAP™ application.

During this reporting period, performance measurements were carried out to evaluate and document the continued mercury removal performance of the MerCAP™ array installed at Site 1. Two sets of MerCAP™ substrates were removed from service and subjected to acid-wash treatment, which proved an effective method of chemically regenerating the plates and improving their overall mercury capture performance. Also at Site 1, Method 324-based carbon traps and Ontario Hydro manual methods were run for verification of the mercury continuous emission monitor (CEM) data and system removal performance.

Work on the MerCAP™ installation at Site 2 included fabrication of the MerCAP™ pilot housing, fabrication of the data logger system, assembly of the gold substrate support frames, and plant site preparations at Georgia Power's Plant Yates Unit 1.

TABLE OF CONTENTS

INTRODUCTION

This document is the sixth quarterly Technical Progress Report for the project "Evaluation of MerCAP™ for Power Plant Mercury Control," (DE-FC26-03NT41993) for the time-period January 1, 2005 through March 31, 2005. The objective of this project is to demonstrate the performance of MerCAP™, a technology that uses a fixed sorbent downstream of wet and dry scrubbers for removing mercury from coal-combustion flue gas. The project is being funded by the U.S. DOE National Energy Technology Laboratory under this Cooperative Agreement. EPRI, Great River Energy, and Southern Company are project co-funders. URS Group is the prime contractor.

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Great River Energy is providing co-funding and technical support to this project and is providing Stanton Station Unit 10 as a host site. Unit 10 fires North Dakota Lignite and Powder River Basin (PRB) subbituminous fuels and is configured with a spray dryer as a dry FGD system, with a downstream baghouse for particulate control. At this site, an array of gold-coated MerCAP™ plates is incorporated into the outlet plenum of one compartment (6 MWe) of the Unit 10 baghouse.

Southern Company is providing co-funding and technical input to this project and its subsidiary, Georgia Power, is providing its Plant Yates as a host site for testing. Plant Yates Unit 1 fires a low-sulfur bituminous coal and is configured with a small-sized ESP for particulate control, and a downstream CT-121 Jet Bubbler Reactor (JBR) wet FGD system**.** Gold-coated structures will be configured in a 2800 acfm slipstream downstream of the full-scale FGD absorber.

The ability to repeatedly thermally or chemically regenerate exposed MerCAP™ plates is a critical component to the overall economics of the technology. Therefore, during the longer-term tests, small-scale tests are being conducted to evaluate the mercury removal effectiveness at both sites following repeated regeneration cycles. Tests are being conducted using a 40-acfm slipstream probe device ("Mini-MerCAP™ probe"). Gold-coated substrates from the same production batch used for the MerCAP™ arrays in the larger longer-term tests are used in the Mini-MerCAP™ probe.

MerCAP™ technology has been successfully tested in small-scale units installed at the host sites. Results of this study will verify this performance at a larger scale and over a longer period of gas exposure and will provide data required for assessing the feasibility and costs of a full-scale MerCAP™ application.

This report describes the activities carried out for this program during the project-reporting period of January 1, 2005 through March 31, 2005. The remainder of this report is divided into four sections: an Executive Summary followed by sections that describe Experimental Procedures, Results and Discussion, and Conclusions.

EXECUTIVE SUMMARY

Summary of Progress

The current reporting period, January 1, 2005 through March 31, 2005, is the sixth full technical progress reporting period for the project. Efforts during the current period focused on tasks associated monitoring and testing the full-scale MerCAP™ array at Site 1 and design and fabrication of components for the Site 2 installation.

Site 1 Activities

Performance measurements were conducted in early January 2005. Two sets of substrates, installed in duct sections 2 and 3 in November 2004, had not been pre-treated with an acid wash. These two sets of MerCAP™ substrates continued to demonstrate poorer performance than the substrates that had been pre-treated. The MerCAP™ substrates installed in duct sections 2 and 3 were removed and subjected to an acid wash treatment. The substrates were then reinstalled and monitored to evaluate mercury removal performance. Samples of the acid wash were taken and analyzed to quantify the amount of mercury removed in the treatment process of the substrates. The acid bath was also analyzed for gold concentration to determine the if there is a significant negative impact of acid washing on the substrates and to determine if "chemical regeneration" is another alternative to thermal regeneration.

Acid wash treatment of the MerCAP™ substrates in ducts 2 and 3 significantly increased mercury capture performance from levels of 15% to over 35%. Chemical analysis of the acid bath solution revealed that less than 0.1% of the gold coating by weight in the plates was etched or stripped off the substrates during the cleaning process, demonstrating that this may be a viable alternative to thermal regeneration of the MerCAP™ substrates.

To date, there has been poor correlation between Ontario Hydro method measurements and mercury CEM results. Method 324-based carbon trap measurements were performed as an alternate method for comparison to the mercury continuous emission monitor (CEM) results. The carbon trap comparison resulted in better than 6% correlation between CEM measurements and the Method 324 approach.

Thermal regeneration of substrates housed in the Mini-MerCAP™ probe was also completed. The same section of gold was subjected to three thermal regeneration cycles. Performance measurements, before and after the thermal regeneration, were used to determine if there were any direct impacts on performance. The gas waste stream exiting the regeneration process was monitored via high capacity carbon traps to attempt a mass balance on the overall process. Performance of the gold substrates improved slightly after each cleaning cycle, demonstrating that multiple regeneration cycles using the same substrate are very feasible. The ability to perform multiple regeneration cycles is critical to the economics of the MerCAP™ technology.

Mercury removal efficiency across the MerCAP™ Array varied with dry spray dryer operating parameters from a high of 63% to a low of 0%. Lower fuel sulfur levels associated with the burning of the PRB fuel have required less severe scrubbing conditions to meet and exceed

emission limits. Specifically, less slurry feed is resulting in higher spray dryer temperatures. The higher temperatures associated with the lower slurry feedrates correlate with degradation in the overall MerCAP™ mercury capture performance. A series of process parametric tests are being considered to better understand this relationship.

Table 1 lists the planned and completed milestones for this project.

Table 1. Schedule for Year 1 Milestones for this Test Program.

Milestone	Description	Planned Completion	Actual Start/ Completion
1	Submit Hazardous Substance Plan	Q1	Q1/Q1
2	Submit Test Plan	Q1	Q1/Q1
3	Frame Installation/Baseline Monitoring Site 1	Q1	Q1/Q2
4	Site 1 Gold Installation, Intensive Testing	Q1	Q1/Q3
5	Start of Long Term Testing, Site 1	Q3	Q3
6	End of Long Term Site 1, Gas Char Tests	Q3	Q3/Q2(2005)
7	Site 1 Review/ Site 2 Planning Meeting	Q3	Q4
8	Frame Installation/Baseline Monitoring Site 2	Q4	Q2(2005)

Site 2 Activities

Tests at Site 2 will evaluate gold MerCAP™ performance downstream of a wet FGD absorber in flue gas derived from Eastern bituminous coal. The fixed sorbent structure will be configured in a flue gas slipstream (approximately 2800 acfm) located downstream of the Plant Yates Unit 1 JBR reactor. The slipstream is part of an existing pilot scrubber setup installed previously by Southern Company. Work during this reporting period included that associated with the design and fabrication of the Site 2 test unit.

Figure 1 is a photograph of the constructed housing that will contain the gold substrates for the MerCAP™ installation at Site 2. Figure 2 is a photograph of one of the three MerCAP™ gold substrate modules that will be installed in the pilot housing.

The unit was completed in February and shipped to the plant where it is currently awaiting installation. The MerCAP™ test unit was not immediately installed at Site 2 due to scheduling conflicts with other DOE test programs on Yates Unit 1 and a planned outage. The test unit will be installed in a long horizontal run of pipe to the inlet of Southern Company's pilot scrubber that was previously identified as the best location for the installation. This location was selected because the MerCAP™ unit could be easily retrofitted into the existing system at this point, and because the run of pipe is relatively close to the ground that will aid in the future sampling activities as well as configuration and installation of the gold plates. The MerCAP™ reactor will be located just upstream of the pilot scrubber (which will not be operated during the MerCAP™

tests). A fan, configured on the pilot unit, will provide the motive force for the flue gas across the MerCAP™ unit. Flue gas exiting the reactor will be flowed back to the Unit 1 duct.

Figure 1. Wet MerCAP™ Housing for Installation at Site 2

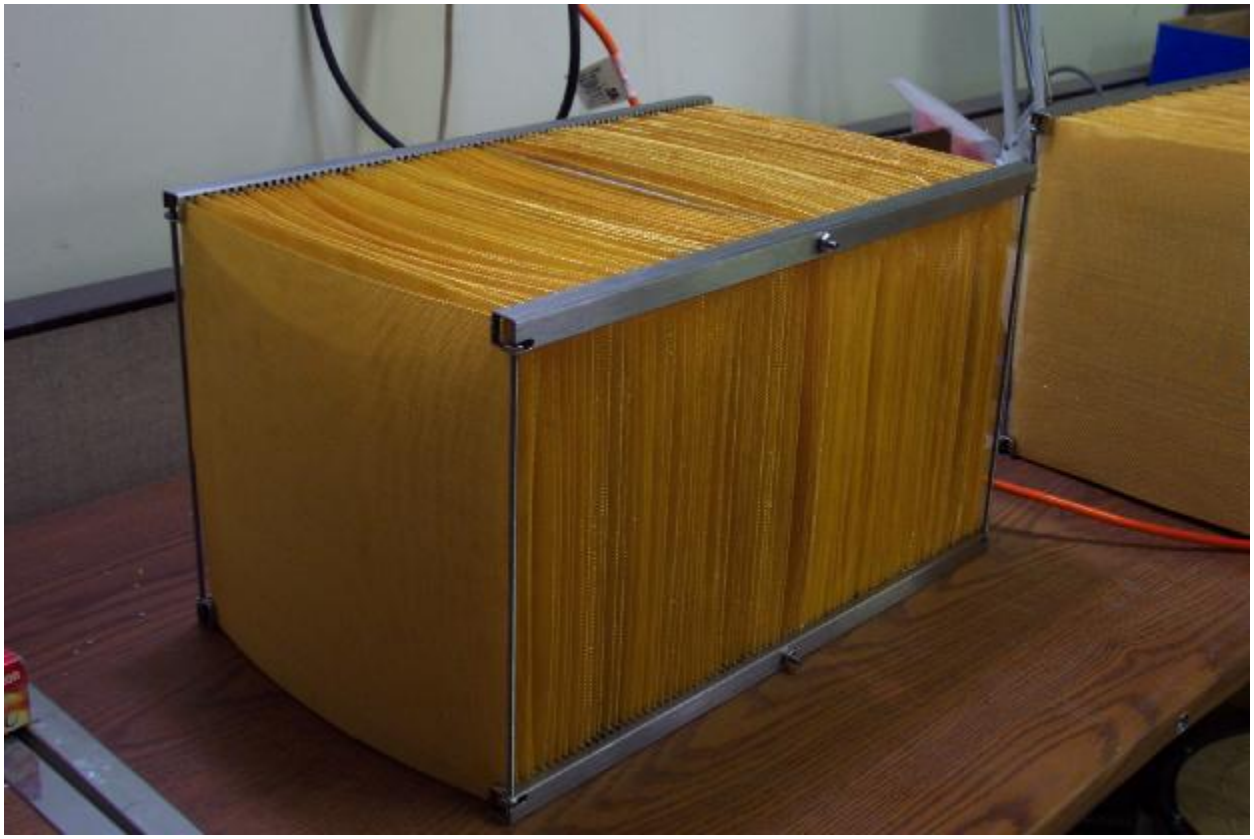

Figure 2. Gold Substrate Module for the Wet MerCAP™ System

The MerCAP™ reactor will be constantly monitored for inlet and outlet temperature, static pressure, pressure drop, and flow. A data logger located on site will continuously collect this data. Ports fitted upstream and downstream of the gold plates will allow access points for mercury measurements, and a wash water system will also be fitted to the system to allow for periodic cleaning of the gold screens.

Other activities performed during this reporting period included extracting coupons of gold plated screens that were inserted into the flue gas at Plant Yates Unit 1. These were exposed to flue gas for three months at three separate locations including the outlet of the ESP, inlet of the JBR scrubber downstream of a quenching spray, and at the stack. The coupons at the ESP outlet and the stack appeared to maintain their integrity and showed no signs of corrosion. The coupon at the JBR inlet, downstream of a quenching spray was almost completely destroyed by the time it was removed from the flue gas. Only one small piece of the screen remained and was highly corroded. The corrosive properties at this location were not completely unexpected, and are most likely due to the spray quenching that would cause acids to condense out of the untreated flue gas.

Sub-Contracts

No subcontracts were awarded during this reporting period.

Task Activity Summary

Table 2 lists the current activity status of the primary tasks for this program. The Stanton MerCAP™ testing had been delayed in the first quarter of 2004 due to operation issues at the host site. MerCAP™ installation and testing has been delayed at Plant Yates Unit 1 due to a conflicting DOE carbon injection program at this host site; the latter was delayed due to schedule constraints associated with performance of a long-term demonstration test. The carbon injection program ended in December 2004, however a scheduled outage at Plant Yates Unit 1 in April and DOE scrubber additive tests further delayed the MerCAP™ installation until the second quarter of 2005. The 6-month operation and testing period for Stanton has been reached and exceeded (7.3 months). Remaining test resources will focus on a better understanding of the plant operating parameters on MerCAP™ performance.

Table 2. Project Activity Status.

Task Number	Description	Planned % Completion	Actual % Completion
1	Project Planning	90%	90%
2	Stanton MerCAP™ Testing	100%	100%
3	Yates MerCAP™ Testing	10%	10%
4	Economic Analysis	0%	0%
5	Project Management & Reporting	45%	45%

Problems Encountered

The continued poor performance at Site 1 of unwashed gold substrates installed in duct 2 and 3 resulted in a demonstration and potential benefit of acid washing the MerCAP™ substrates as a viable alternative to thermal regeneration. Mass balances were conducted on both the chemical and thermal regeneration processes. Initial runs showed poor correlation, typically 1 order of magnitude lower recovery than estimated. The parameters associated with the regeneration techniques, primarily treatment time, will be varied in future runs, and sampling methods will be slightly modified to better collect high concentration mercury streams being released off the substrates during the regeneration processes.

To date, there has been poor correlation between data collected via the Ontario Hydro method and the mercury CEM. During this reporting period Method 324 traps were run and resulted in excellent comparison with CEM values. Future comparison runs will attempt to run Ontario Hydro, CEM, and Method 324 trains simultaneously.

Plant operation with lower sulfur fuel has modified spray dryer operating parameters, often resulting in poorer mercury capture across the MerCAP™ Array. The relationship of plant slurry feedrates and spray dryer outlet temperatures to MerCAP™ performance is being further investigated. Encouraging, however is that this performance degradation appears to be transient with the operating conditions and does not cause a permanent impact on the MerCAP™ substrates.

The installation of the MerCAP™ test unit at Site 2 was delayed at the request of the host site due to conflicts with a planned outage in April and other mercury related DOE projects scheduled to occur simultaneously with the MerCAP™ at Plant Yates Unit 1. In order to minimize interruption of the MerCAP™ testing, it was determined that the best time for start-up would be after the scheduled April outage on Unit 1. The start-up schedule was also impacted by DOE scrubber additive tests that have potential to reduce the flue gas mercury concentration entering the MerCAP™ test unit. It was determined that the best course of action would be to perform the scrubber additive tests immediately after the outage, and follow with the MerCAP™ tests in the first half of June.

Plans for Next Reporting Period

The next reporting period covers the time-period April 1 through June 30, 2005. During this quarter, the long-term testing and evaluation of the MerCAP™ array installed at Stanton Station will be completed. An additional series of Ontario Hydro measurements will be made to verify the performance and accuracy of the mercury CEM utilized during periodic performance evaluations. Additional thermal regeneration cycles will be run with modified sampling and operation techniques to further improve the mass balance of the overall process.

The MerCAP™ reactor for Site 2 will be installed during the next reporting period. The system will be put into service without gold plates and baseline mercury measurements will be made. The gold plates will then be installed after the baseline period and initial mercury measurements will be collected across the unit.

Prospects for Future Progress

The planned demonstration under the DOE-funded effort at Site 1 is coming to completion. The possibility of continued operation and sources of funding for the MerCAP™ testing at the host site is being investigated. At 5300 hours of operation, 7.3 months of service, the mercury removal performance has been averaging 30% on the original module of gold substrates. The primary detrimental impacts on the technology appear to be spray dryer operating conditions and duct temperature excursions, both of which appear to only have a temporary impact. Additional parametric tests at Site 1 and pending results from Site 2 should help with understanding the mercury gold amalgation process in the presence of flue gas.

RESULTS AND DISCUSSION

Performance Measurements

During this reporting period three sets of performance measurements were made to evaluate mercury removal of the installed MerCAP™ substrates at Stanton Station. In addition to the three sets of mercury CEM measurements, carbon trap-based measurements, and a set of Ontario Hydro measurements were conducted to verify mercury removal performance. Carbon traps were used to measure inlet and outlet mercury concentrations across the MerCAP™ Array. These carbon trap measurements were conducted simultaneously while the mercury CEM was operating. The carbon traps were first connected to the sample extraction system that conveys the flue gas from the compartment to the mercury CEM. The carbon traps were physically connected to sample ports on the inertia gas separation (IGS) filters used to assure a particulate-free gas sample to the instruments. The intent of these carbon trap runs was to verify the CEM performance independent of the sample extraction system. The comparison data is presented in Table 3. The carbon trap data and the mercury CEM data are both corrected to 3% oxygen concentrations. The mercury CEM data is an average of all collected data points at the specific test location between the logged start and stop times for the carbon trap run. The calculation for lb/TBTU was based on an f-factor for bituminous fuel of 9780 dry scf/MBTU at 0% O_2.

Table 3. Mercury CEM and Carbon Trap Measurement Comparisons

Mercury CEM			Carbon Trap		
Inlet Total	Outlet Total	Removal (%)	Inlet Total	Outlet Total	Removal (%)
4.29 (ug/nm^3)	3.35 (ug/nm^3)	22.0	4.56 (ug/nm^3)	3.48 (ug/nm^3)	23.7
2.85 (lb/TBTU)	2.22 (lb/TBTU)		3.03 (lb/TBTU)	2.31 (lb/TBTU)	

% difference in removal: -7.8
% difference in Inlet: -6.3
% difference in Outlet: -4.0

Potential losses or biasing of the gaseous mercury concentration in the extraction and filtration portions of the CEM systems is a concern. The CEM system includes two independent extraction manifolds, IGS filters, and pumps for both the inlet and outlet of the MerCAP™ Array. The heat-traced system is fabricated from type 316 stainless steel tubing and pipe, sized to provide a high volume flow of 200 liters per minute (lpm) up to and through the independently heated IGS filters. A 2-lpm flow of gas is continuously pulled through the IGS filters to the CEM sample conditioning system.

To verify performance of the sample extraction system, a set of carbon traps were run concurrently with one sampling while connected to the IGS at the CEM outlet extraction location, and the second was installed on the end of a probe and inserted directly into the

compartment at the outlet of the MerCAP™ Array. The carbon trap installed directly into the baghouse compartment (MerCAP™ Array outlet) uses the same sample port and probe length as an Ontario Hydro sampling train. The carbon trap identified as the "Outlet OH Port" is fully immersed in the duct flue gas and has no fittings or sample tubing attached to the inlet of the carbon trap. The carbon trap identified as "Outlet IGS" has approximately 14 linear feet of heat-traced stainless steel tubing conveying a high volume sample to the IGS filter. The results of this run are presented in Table 4.

Table 4. Mercury CEM Extraction System vs. Ontario Hydro Sample Port

Mercury CEM	Carbon Trap	
Outlet Total	Outlet OH Port	Outlet IGS Port
3.82 (ug/nm^3)	3.96 (ug/nm^3)	3.83 (ug/nm^3)
2.54 (lb/TBTU)	2.63 (lb/TBTU)	2.54 (lb/TBTU)

% difference in CEM vs. Carbon Trap at Outlet IGS: -0.3
% difference in carbon trap at IGS vs. OH Port: -3.3

The results of these measurement efforts were very encouraging. The CEM and carbon traps run side by side at the IGS filter were with 1% of each other, and the carbon trap to carbon trap results between the IGS filter on the end of the extraction system and the direct duct measurement were within 5%. The use of an extractive sample system of this complexity was possible at this host site as the installation is on the "clean-side" of baghouse with a fairly benign flue gas which typically has more than 90% of the total gaseous mercury in the elemental form.

During the third week in January 2005, the MerCAP™ substrates that had been installed in ducts 2 and 3 were removed from service and subjected to acid washing. These substrates, when installed in November 2004, had not been subjected to an acid-wash pretreatment. The goal had been to evaluate performance differences due to treated and untreated substrates. The original treated substrates installed in August 2004 have continually outperformed the un-washed substrates. The MerCAP™ substrate modules in ducts 2 and 3 were removed from service and shipped to Denver for acid wash treatment. The details of this process are described in the later section on chemical regeneration. After acid washing, the substrates were returned to service. Mercury removal performance improved significantly after acid washing. MerCAP™ substrates installed in duct 2 are configured with 1" plate spacing, identical to the substrates in duct 1. Mercury removal efficiency improved from 10% to 52%. Similarly the ½" spaced substrates that were reinstalled in duct 3 after washing improved from 12% to 58% mercury removal. A summary of the status of the MerCAP™ substrates is provided in Table 5.

Table 5. Substrate Summary

Duct Section	Substrate	Plate Spacing	Install Date	Hours in Service	Average Hg Removal	Measured Outlet Oxidized Hg
Duct 1	Acid Treated	1-Inch	8/22/04	5,308	30 – 35%	35 – 40%
Duct 2	Non-Acid Treated	1-Inch	11/18/04	1,035 1,470	15 –18% 10%	20%
Duct 2	Post Acid Treatment	1-Inch	1/25/05	Reinstalled after regen	52%	N/A
Duct 3	Non-Acid Treated	½-Inch	11/18/04	1,035 1,470	25 – 30% 12%	20 – 25%
Duct 3	Post Acid Treatment	½-Inch	1/25/05	Reinstalled after regen	58%	N/A
Duct 4	Empty/Baseline	N/A	N/A	N/A	0%	15%

Figure 3 details the performance of the MerCAP™ array in duct 1 from the initial installation to the end of this reporting period. Mercury removal performance is calculated as the percent of incoming (inlet) mercury removed by the substrates. Service time is calculated in hours of service from the time of installation.

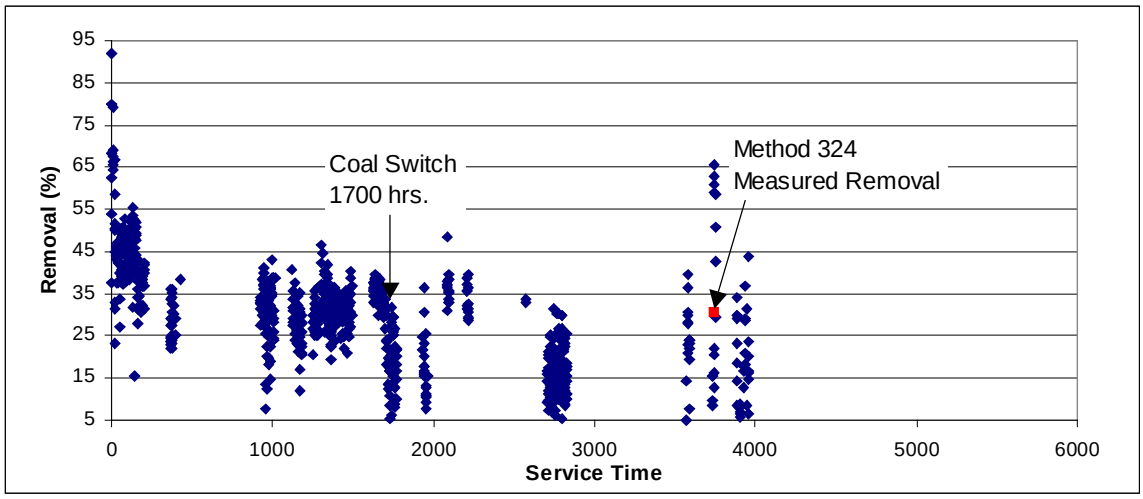

Figure 3. MerCAP ä Performance versus Service Time, Site 1

The removal performance in Figure 3 near the 4000-hour service time shows a wide variability. Evaluation of plant data, specifically lower slurry feedrates, and higher spray dryer outlet temperatures, correlate strongly with the degradation in performance. Earlier examination of the program data had identified the relation of poor removal with increased flue gas temperature. Specific periods of plant operation have been observed where good removal performance has occurred during higher temperature operation. This only happens if the slurry feedrate is at a high level. A parametric evaluation of this correlation will be attempted in the next quarter.

Regeneration Testing

The ability to repeatedly regenerate exposed MerCAP™ plates, by either a thermal or chemical process, is a critical component to the overall economics of the technology. A series of small-scale tests were conducted to demonstrate the mercury removal effectiveness of the substrates following repeated regeneration cycles.

Tests were conducted using the 40-acfm slipstream probe device ("Mini-MerCAP™ probe"). The Mini-MerCAP™ probe is installed on the outlet duct of Stanton Station Unit 10, downstream of the baghouse. This probe contains a ten-foot long by two-inch wide section of gold-coated substrate from the same production batch installed in the MerCAP™ arrays being tested in compartment 6 of the baghouse. Flue gas was extracted via heated lines from the host duct, directed down the length of the Mini-MerCAP™ probe and then returned to the duct. The inlet and outlet mercury concentrations are measured via sampling ports at the inlet and outlet of the probe using a CEM. After exposure to flue gas for set periods, followed by removal performance measurements, the MerCAP™ substrate is removed from the probe and placed in a sealed chamber in a heated oven. The regeneration oven is brought to temperature and a flow of clean dry air is directed across the substrate in the chamber. This gas stream is then directed through a high capacity mercury carbon trap outside the oven for quantification of the mercury desorbed from the gold substrate. At the end of the thermal regeneration cycle the substrate is reinstalled in the Mini-MerCAP™ probe and post regeneration mercury removal performance is again measured using a CEM.

Thermal Regeneration

The results of three regeneration cycles are shown in Table 6. Oven temperatures of 750-800 ^{o}F and a regeneration period of typically 12 hours were used. A simple estimate of the total mercury expected to be captured on the substrate was conducted. These estimates are based on time in service, inlet mercury concentration, total volume of flue gas treated, and average removal efficiency. Inlet mercury concentration assumed was 5 ug/m^3, 30 acfm of flue gas at 200 ^{o}F, and a removal efficiency of 30%.

Table 6. Thermal Regeneration Results

Run Number	Oven Temperature (^{o}F)	Duration (Hrs)	Mercury Recovered (milligrams)	Post Regeneration Mercury Removal Performance
104	797	12.9	4.9	26%
101	752	14.1	11.1	34%
107	752	12.9	0.4	45%

The substrate, when subjected to the first regeneration cycle, had been in service for over one month duration and would have potentially captured as much as 45 milligrams of mercury. The mercury recovery from the first regeneration was 4.9 milligrams, an order of magnitude less than

estimated. The second regeneration cycle was conducted after an additional 12 hours of operation in duct. During this 12-hour operation period the MerCAP™ substrate should have captured 0.7 milligrams of mercury. Analysis of the carbon trap for the second regeneration cycle showed a mercury recovery level of 11 milligrams, higher then the first regeneration. The discrepancy between the measured and the estimated mercury recovery rates may be due to inadequate regeneration time during the first cycle, or residual higher concentrations during the first regeneration cycle may have condensed out in the outlet sample extraction system, and were then carried over during the second regeneration run. The third run measured a recovered mercury level of 0.4 milligrams, much closer to the predicted level of 0.7 milligrams. Future thermal regeneration cycles will be lengthened in duration in an attempt to improve the closure between estimated and actual recovery of captured mercury.

The post regeneration performance of the substrate demonstrates that at three thermal regeneration cycles there is no measurable negative impact on the capture performance of the MerCAP™ substrate. Removal efficiencies actually increased after each regeneration cycle. The data would indicate that the duration of the regeneration cycle (12 hours) may not be adequate to completely drive off the mercury bond to the substrate, and future cycles will be conducted for longer periods of time.

Chemical Regeneration

The MerCAP™ substrates installed in ducts 2 and 3 of the baghouse compartment were non-acid treated when initially installed in November 2004. Removal performance of these substrates lagged compared to that which was measured on the acid-treated substrates in duct 1.

The gold substrates of ducts 2 and 3 were removed from service on January 18, 2005 and shipped to Denver for acid treating/cleaning. After treatment the plates were re-installed into the ducts and were measured for mercury removal performance on January 25, 2005. Before treatment the plates had been removing 10-12% and immediately after the acid treatment the removal efficiency increased to 52-58% (see Table 5).

The acid treatment used is a Type VI passivation technique. This is a bath consisting of a 30% nitric acid in water held at room temperature. The treated material is immersed in the bath for a 30-minute soak time and then rinsed with distilled water. The electroplating industry uses a Type VI bath to passivate and clean products in preparation for plating. The bath functions by etching away acid-soluble elements and compounds. In the case of the MerCAP™ gold substrates, any contaminants in the gold or at the surface of the gold coating layer should be dissolved in the solution leaving a pure gold layer. The electroplated gold substrate has a high corrosion resistance to the acid bath, yet mercury or mercuric compounds that have formed on the surface or amalgamated into the gold structure are dissolved into the bath solution.

A fresh Type VI bath was prepared to clean the MerCAP™ substrates removed from ducts 2 and 3. Liquid samples for analytical analysis were taken from the bath prior to use, and at nine intervals between cleaning MerCAP™ modules. The 10 MerCAP™ modules removed from ducts 2 and 3 were processed through the bath one module at a time for 30 minutes each. Thus the mercury concentration in the baths was expected to increase as more modules were washed.

These samples were subjected to ICP Mass Spectroscopy for evaluating a suite of elements, including gold, and mercury via CVAA-based Method 7470. The results of the bath analysis for mercury content are shown in Figure 4 below. Mercury concentrations in the bath increased as expected with the final concentration peaking at 2630 micrograms per liter (ug/L).

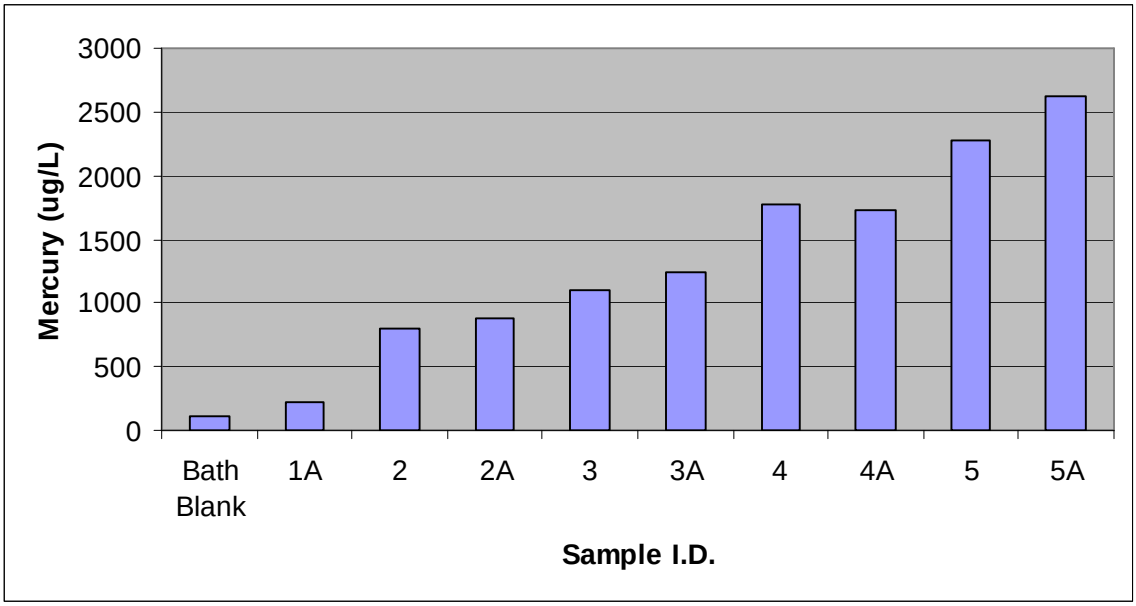

Figure 4. Chemical Regeneration Bath Mercury Concentrations

The final bath concentration and the bath volume were used to determine the total mercury removed from the plates by the cleaning process. A total of 0.8 grams of mercury were removed via the chemical regeneration process. The simple estimate of the total mercury captured in the two duct sections is based on time of operation (61 days), average mercury inlet concentration (4 ug/m^3 – 2.66 lb/TBTU) and average gas flow treated (170 sm^3/minute) and the average removal rate over the period (15%). The estimate is that the MerCAP™ modules in ducts 2 and 3 should have captured approximately 9 grams of mercury during their time in service. The order of magnitude difference in the estimated captured versus recovered mercury is being further investigated. There was no attempt to determine the effect of soak time of the MerCAP™ modules in the acid bath on mercury removal, so it is unclear if additional treatment time would have improved the closure of the estimated versus recovered mercury. Additionally there was no attempt to hermetically seal the modules when they were removed from service and transported to the processors. Out gassing of mercury off the MerCAP™ modules when removed from service is a potential area of concern that needs further investigation.

The amount of gold measured in the regeneration bath was also monitored to determine if the chemical regeneration process would significantly damage or remove the gold coating. The gold concentration measured in the final bath was a mass of 0.6 grams. The gold electroplated onto the 10 MerCAP™ modules that were cleaned in the bath had a net mass of gold on them of 1800

grams (64 ounces). The loss or damage to the gold coating due to acid washing is less 0.1% by weight, suggesting that the chemical regeneration process could be utilized on the same set of MerCAP™ plates repeatedly with minimal damage or degradation.

The chemical regeneration bath was also analyzed for a suite of elements that are thought to possible interact or interfere with the mercury amalgamation process. The bath blank and final bath concentrations for these elements including mercury and gold are show in Figure 5. The plates were not subjected to an extensive rinse or pre-wash process so a portion of the analytes that were measurable in the final bath could potentially be attributed to residual ash that was bound on the substrates. However, the substrates were visibly clean and a white glove wipe of the surface resulted in little to no visible particulate pick-up. Previous testing of small batches of MerCAP™ substrate samples had been subjected to a distilled water rinse in an ultrasonic bath in an effort to eliminate fly ash surface contaminants from biasing the analysis. The results of those test produced comparable proportions of the measured analytes, suggesting that these elements are being captured from exposure to flue gas. The exceptions to these elements are the nickel and chromium that are present in clean unexposed substrates. These elements are in high concentrations in the base or strike plate that is used in the electroplating process to improve the bond strength of the gold layer.

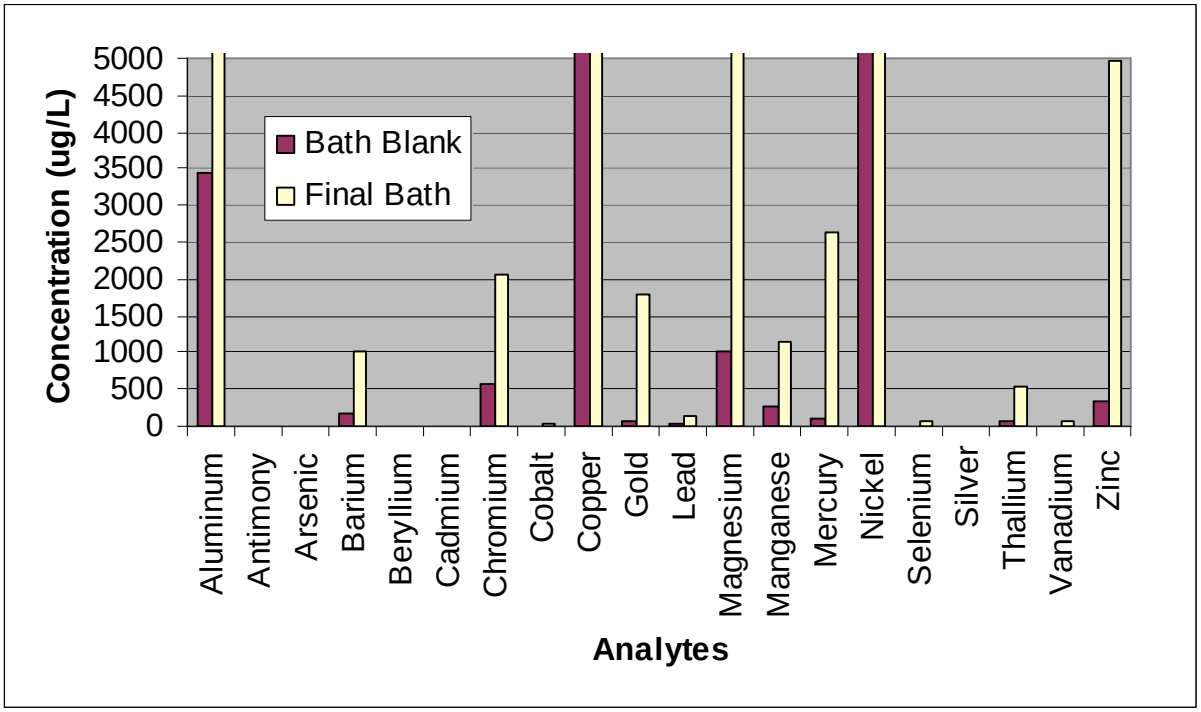

Figure 5. Chemical Regeneration Bath Analytes

Effect of MerCAP™ Technology on Differential Pressure

The MerCAP™ concept has been primarily envisioned as a retrofit technology. After modification of a baghouse compartment or an outlet duct section to house the MerCAP™ arrays,

the other primary impact of the technology on plant operation is an increase in differential pressure due to the flow resistance as the flue gas passes through the plate channels. Instrumentation was incorporated into the demonstration to measure and record the effect on differential pressure due to the MerCAP™ installation and operation.

Two of the ten host baghouse compartments are monitored with the data acquisition system. Baghouse compartment 1, housing the MerCAP™ Arrays, and compartment 6 (no arrays) are mirror images of each other at the inlet end of the Stanton Station Unit 10 baghouse. The tube sheet differential pressure drop (pressure drop across the filter bags) is monitored in both compartments to determine the overall impact of the MerCAP™ Array on the baghouse compartment. Additionally, the pressure drop specifically across the MerCAP™ Array is monitored within compartment 1.

As a result of the MerCAP™ Array installed in compartment 1, an average increase in the differential pressure of 1.5 inches of water (in-H_20) has been recorded compared to the adjacent compartment 6. Prior to installation of the MerCAP™ substrates, the physical duct structures installed in the top of compartment 1 to house the MerCAP™ Array resulted in 0.15 inches of water of the total reported pressure increase. These duct sections force the gas exiting the bags filters to pass through the MerCAP™ substrates prior to exiting the compartment. The MerCAP™ ducts have fairly severe entrance and exit planes. Severe changes in entrance and exit areas are often associated with increased flow resistance. A permanently installed MerCAP™ system could be more thoroughly engineered to minimize these entrance and exit losses.

The measured increase in pressure drop is 0.5 in-H_20 higher than previously measured on a pilot unit at the same host site. The full-scale compartment installation differs in that it requires a wire frame to support the larger (2-foot by 2-foot) module sections and thus presents a slightly higher cross sectional area than the 8-inch wide substrates used in the pilot. Gold electroplating equipment has been identified that would allow production of larger substrate sections that would not require the wire support frame.

Individual Pitot probes are installed at the outlet plane of each of the four ducts housing the MerCAP™ modules. These Pitot probes provide a measure of the gas velocity exiting the individual duct sections and thus any significant variation in flow between the parallel ducts housing the MerCAP™ modules.

The MerCAP™ plates installed in ducts 1 and 2 are configured with a 1-inch plate to plate spacing. MerCAP™ plates were installed in duct 3 that utilize a ½-inch plate to plate spacing. The narrower channels and larger surface area of the gold substrates in duct 3 resulted in a 21% decrease in flow through that duct section as compared ducts 1 and 2. Since the ducts share a common large entrance and exit plenum they experience a comparable differential pressure across all ducts. The ducts with least flow resistance (ducts 1 and 2 with 1-inch spacing) treat a larger volume of gas than a duct with a higher flow resistance. Gas velocities in ducts 1 and 2 increased from nominally 19 feet per second to 24 feet per second. No degradation in the mercury capture efficiency of the MerCAP™ substrates in ducts 1 and 2 was measured due to the

increase in flow. Modeling data and pilot data have shown the mercury capture or removal efficiency is fairly flat for a range of gas velocities from 15-45 feet per second.

The impact of the additional differential pressure across the host boiler will be addressed in the economic analysis by impact of additional yearly power required to overcome the resistance. Plants considering MerCAP™ technology that have marginal induced-draft fan capacity will have to include the capital cost of fan upgrades.

CONCLUSIONS

MerCAP™ technology has been in continuous operation for over 5300 hours (7.3 months), as of March 31, 2005 at Site 1, a spray dryer baghouse unit. The first 1700 hours of service were in operation with ND lignite coal, and the remaining service hours have been with PRB coal. Mercury removal efficiencies have averaged 30-35% during this time period.

During periods of poorer removal performance a correlation to spray dryer operating parameters has been observed and is being further investigated. Under some spray dryer conditions removal efficiencies as high as 65% have been measured.

Method 324-based carbon traps were run simultaneously with mercury CEM measurements. The results of these comparison measurement methods demonstrated strong agreement. Previous Ontario Hydro method and CEM measurements have not correlated well.

Testing during this reporting period has demonstrated that an acid pre-treatment of the MerCAP™ substrates has a significant effect on the overall mercury removal performance. MerCAP™ substrates that had not been acid washed were performing poorly. The removal performance of these substrates improved significantly after they were removed, acid washed, and reinstalled.

During this reporting period, a set of MerCAP™ substrates were subjected to three thermal regeneration cycles. Measurement of the post regeneration performance demonstrated no measurable negative impact on the capture performance of the MerCAP™ substrate. Removal efficiencies actually increased slightly after each regeneration cycle.

During this period it was also learned that acid washing of exposed MerCAP™ substrates is a feasible alternative to thermal regeneration.

The differential pressure across baghouse compartment 1 containing the MerCAP™ Array has averaged 1.5 in-H_20 higher than that measured across the adjacent compartment. This differential pressure increase is higher than that predicted and previously measured on similarly configured MerCAP™ probes. Sharp entrance and exit plenums and additional support structure are believed to be the cause of this. A permanently engineered design may minimize these non-ideal losses.

REFERENCES

No References.